

FMC Corporation
Engineered Systems Division

(NASA-CR-160993) FOOD PACKING OPTIMIZATION
Final Report (FMC Corp., Chicago, Ill.)
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FINAL REPORT

FOOD PACKING OPTIMIZATION

CONTRACT NAS9-16064

PREPARED FOR

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

LYNDON B. JOHNSON SPACE CENTER

HOUSTON, TEXAS

1.0 INTRODUCTION

This final report is presented in summary form showing results of an investigative and developmental program to devise a universal closure lid for the Space Shuttle food package.

2.0 SUMMARY AND BACKGROUND

2.1 SUMMARY

Background information on the design closure lid for the Space Shuttle food package indicated that the design approach with only three depths of lids did not fulfill the requirement for a nesting container accommodating varying food volumes, etc. A revised lid design was therefore necessary.

The design approach for the revised lid was to have a folded configuration which, in its unfolded condition, would fully conform to the interior surface of the food cup. This lid, when sealed to the cup, would unfold only to the extent of the volume of food contained, and thereby accommodate an infinite number of fill volumes.

Experimental thermoform molds were fabricated and test lids formed. These lids were tested by filling food cups with various volumes of simulated food. All volumes of food were accommodated from maximum to zero. The lid material not in contact with the food conformed to the cup interior without wrinkles, thus permitting full nesting of the cups. The seal strengths ranged from 13 to 16 pounds per inch, exceeding the required 12 pounds per inch.

The lid development program for the revised lid design and sealing head modification had progressed successfully, and sufficient funds remained to permit fabrication of the production-type thermoformer mold. The final lid design was established and thermoform tooling for the AAA Model MBE 2121A Thermoformer (Plastic Enterprise, Incorporated) was designed and fabricated. Lids formed on these molds were tested for strength and averaged 17 pounds per inch strength.

To improve seal head performance the heating elements were replaced and repositioned to eliminate any hot spots which may have caused head warpage.

The method of mounting the seal head to the ram cylinder was improved by providing a spherical seat to allow the head to tilt and level itself when in contact with the lid/cup assembly. This assured uniform contact pressure over the entire seal area.

2.2 BACKGROUND

The food package design concept is a rigid plastic cup to contain the food and a flexible plastic film lid, which is heat sealed to the cup in a vacuum chamber. The flexible lid protects the food during storage prior to use, aids in rehydration, and helps in reconstitution and mixing of the food prior to consumption. The operation of vacuum packing and lid sealing is performed in an Evacuate, Flush, and Seal (EFS) machine (FMC Drawing 5136860).

The initial concept for a closure lid used lids of three different depths to accommodate the variety of food types and serving volumes. These three lid depths do not accommodate all planned food servings. Some of the food serving fill levels result in an open space between the food and the lid, which limits the amount of vacuum obtained or causes undue stress on the sealed lid. Large food volumes which are sealed with a shallow lid do not permit successful kneading operations to enhance rehydration. Each of the various lid depths also have different flange thicknesses which require different sealing conditions for optimum sealing.

To overcome these difficulties, a revised lid concept is required which will allow efficient packaging at high internal vacuums, reduce the inventory of a number of lid depths, standardize sealing conditions, and enhance rehydration. In addition, the revised lid configuration will improve the nesting characteristics of the sealed food packages and modify the sealing operation to provide a more uniform sealing pressure over the entire sealing path.

3.0 OBJECTIVES

3.1 REVISE LID DESIGN

The lid design will be revised to provide the least number of lid designs to satisfy the following requirements:

- All product fill heights
- Packaging at lower pressure
- Nesting of packages on each other.

The portion of the lid which, as a result of vacuum, comes into contact with the internal wall of the cup shall be wrinkle free.

The lid material must lie on top surfaces of the food product as a result of vacuum sealing, regardless of product fill height. Only that portion of the lid material in contact with the product may contain wrinkles.

The lid material in its final resting position against the product must have a dome or other surplus material that can be gripped by finger action after rehydration to knead the product to enhance reconstitution.

3.2 MODIFY SEAL HEAD DESIGN

The seal head design is to be modified to provide a more uniform pressure profile along the entire circumferential sealing path.

The seal head die shall produce a finished package with an average seal strength (along the entire lip circumference path) of not less than 12 pounds per inch and with no individual sample less than 10 pounds per inch.

3.3 DESIGN LID THERMOFORM MOLDS

Engineering drawings of the thermoform mold to fabricate the final lid design shall be provided. The molds shall be compatible with the AAA Model MBE2121A Automatic Thermoformer (Plastic Equipment, Incorporated).

3.4 DOCUMENTATION

The following documentation is required:

- A progress report to summarize all the work accomplished up through the period of lid and seal die optimization
- A final report to summarize the results of the total contract work.
- An engineering drawing of the final lid design.

4.0 GOVERNMENT-FURNISHED EQUIPMENT AND MATERIAL

To aid in accomplishing the work on this contract, the following equipment and material was supplied:

- Laboratory-type vacuum packaging machine (1)
- Seal head die (1)
- Laboratory bench top thermoformer (1)
- Springborn #SLMS 2192.3.4 lid stock (250 feet)
- Shuttle Food Package Cups, Part Number 47D246503 (250 each)
- Septums, Part Number 47C246504 (250 each).

5.0 TECHNICAL APPROACH

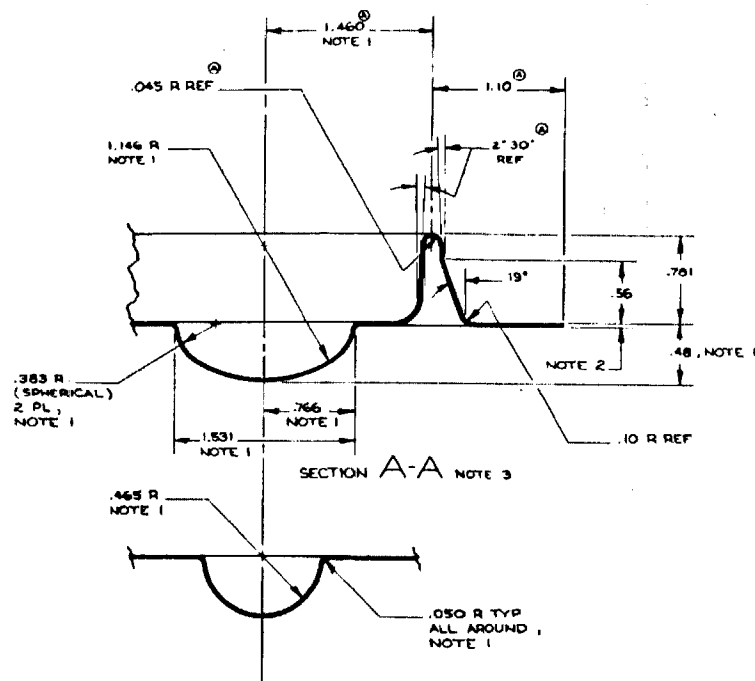
An initial planning meeting between the FMC and NASA project personnel was held at the NASA Houston facility. It was established that a single lid design would be desirable. Such a design will accommodate infinitely varying food volumes within the maximum cup volume.

The selected lid design will, in its fully unfolded condition, conform to the interior surfaces of the food cup. Folding this shape by raising the bottom surface up to the level of the sealing surface resulted in the shape of a lid design to be fabricated. Modifying this configuration to permit fabrication of this shape resulted in the universal food package lid shown in Figure 1 (FMC Drawing 5153663).

Developmental tooling was fabricated by casting a molding compound into a food package cup and then machining the resulting casting into the desired lid cross-sectional shape. This mold was then used with the bench top thermoformer to shape the developmental lids. The Springborn stock was used to form test lids. This stock was a nominal 20-mil thickness. Test lids were also formed from 12-mil-thick polyethylene stock.

Testing was performed with the finished lids to determine optimum seal head temperature, pressure, and dwell time to result in the desired sealing strength.

Finished lids were then applied to the food cups filled to various volumes with Uncle Ben's Instant Rice as a food substitute. Vacuum packaging and sealing was accomplished using the laboratory vacuum packaging machine and seal head. The lids conformed to the contained food as desired. Samples of these lids and resulting packages were sent to the project personnel at NASA Houston for evaluation.



SECTION A-A NOTE 3

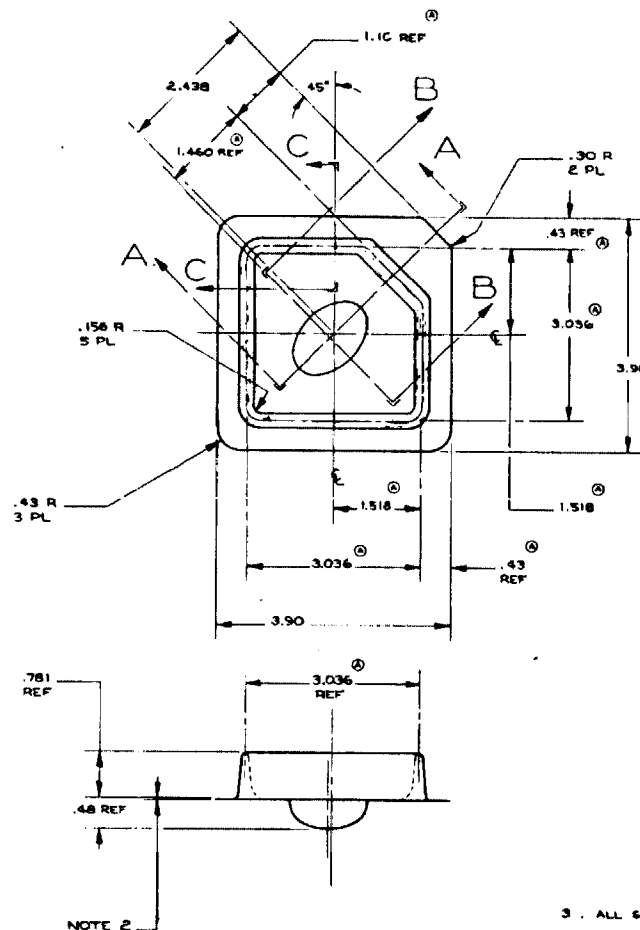
SECTION B-B NOTE 3

SECTION C-C NOTE 3
TYP, 4 PL

PART NUMBER	CONFIGURATION	MATERIAL
5153663 - 2	LESS 660 SHAPED ROCKET	.020 THICK
5153663 - 1	AS SHOWN	.020 THICK
VARIATIONS		

FOLDOUT FRAME

SHOWN IN OUTLINE



FOLDOUT FRAME 2

FOLDOUT FRAME

3. ALL SECTIONS: SCALE = 2 X
2. SEE CHART FOR MATERIAL VARIATIONS
1. SEE CHART FOR CONFIGURATION VARIATIONS

NOTES:

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Figure 1 UNIVERSAL FOOD PACKAGE
LID

Technical evaluation by NASA Houston resulted in an improved lid configuration. The initial mold was modified to accomplish the desired design. More test lids were fabricated for testing both lid conformity and seal strength.

5.1 RESULTS

The universal food package lid, as conceived, meets all the objectives given in Subsection 3.1. The lid, when sealed to the cup, is in intimate contact with the internal surface of the cup without wrinkles. The cups with food filled to various volumes nest to the fullest extent to where the bottom of the top nesting cup contacts the top level of the contained food in the lower cup. Excess material is provided in the lid design in the shape of a dome to provide a means of gripping the lid to aid in the reconstitution process, and lifting the lid to be removed when food is consumed.

5.2 SEAL STRENGTH

Seal strength tests were performed by cutting 1-inch strips in the lid film of the sealed food packages: one each strip on both the cup sides adjacent to the septum opening and two each strips on the two remaining sides of the cup. This resulted in six test strips per cup. The free ends of the strips were then clamped in supporting jaws and hand pulled using a Chatillon Model DPPH Push-Pull Gage to obtain the strip failure loads. Alternating strips on the cups were pulled in either shear (parallel to the seal plane) or in peel (normal to the seal plane).

These tests were performed on cups sealed with lids made from the 20-mil Springborn film. Table 1 presents a summary of the final developmental lid design seal strengths. Twelve tests each in shear and peel were performed at 11 seconds dwell time, and six tests each were performed at 12 seconds. The shear tests more nearly represent the actual loading condition that the sealed lid will experience and therefore are more meaningful. The strength requirements are based solely upon this test. Peel tests provide an additional means of seal evacuation but do not apply to the above strength requirement.

Table 1 AVERAGE SEAL STRENGTHS, FOOD PACKAGE LID

Seal temperature	Seal pressure, PSI	Seal time, seconds	Shear load, pounds per inch	Peel load,* pounds per inch
400	35	11	Δ 13.5 Low 10 High 19	Δ 7.7 Low 6.5 High 11
400	35	12	Δ 16.6 Low 12 High 22	Δ 8.5 Low 5 High 11

*Peel test not a requirement. Information only.

6.0 SEAL HEAD MODIFICATIONS

The continuous operation of the sealing machine during the seal-strength tests resulted in failure of the heating elements in the seal head to the extent that it was no longer possible to maintain an adequate seal platten temperature.

The head was disassembled and new heating elements were ordered from Electrofilm, Incorporated. While in contact with Electrofilm, the problem of heating element failure was discussed. It was decided that the heating element failure could be attributed to poor design of the sealing head because the arrangement left insufficient space for installation of standard heating elements. In addition to the design deficiency, the heating elements were not installed with great care, causing hot spots to develop in the overlap areas of the pads.

Another problem occurred during the heating element operation; the heating element cushions were not relieved at the points of overlay. This created a double thickness which caused excessive compression of the pads at the hot spots. This localized heating melted the rubber and distorted the heating elements. It is also likely that the lumps in the heating element caused warpage observed in the plattens, resulting in uneven seal pressure.

A careful analysis of the problem indicated that there are regions in the heating elements that can probably tolerate being overlapped if pinching is avoided by proper relief of the rubber cushions. There is an unheated region approximately $3/8$ inch square in one corner of the element where the leads are attached. The balance of the element is of relatively high watt density, and failure to properly heat-sink all of this region of the element will probably result in reduced life and premature failure of the heater.

If care is taken to install the element, ensuring all portions of the element remain in contact with the heating platten (except where the leads are attached), then the present standard 1-inch by 3-inch elements should be sufficient. A small amount of overlap will still exist because of the current design. An engineering drawing has been prepared to illustrate the correct and incorrect method of heating element installation and is included in this report (see Figure 2).

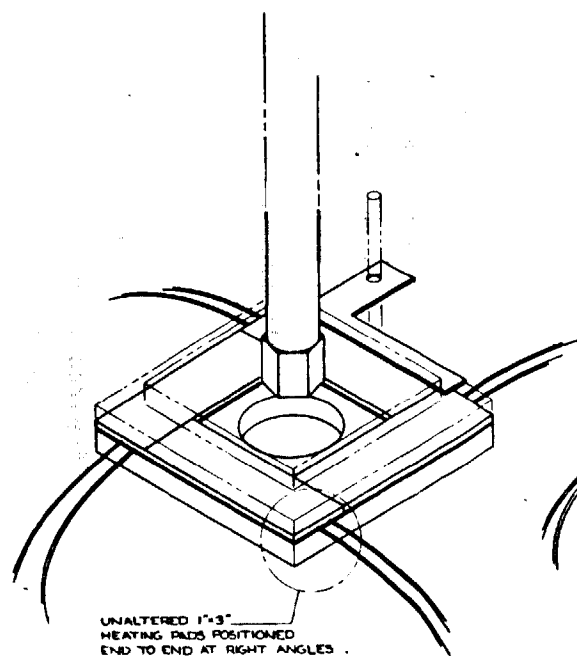
During reassembly of the sealing heads, the elements are installed with all of the lead attachment ends facing away from the plattens. Then the rubber cushions can be carefully fitted to avoid a double thickness at the regions of overlap.

If the operator elects to use the old elements with the cushions attached, he must trim away the excessive cushion at the region of overlap, as the actual heating element is only 40 to 50 mils thick, whereas the cushion is roughly 1/8 inch thick.

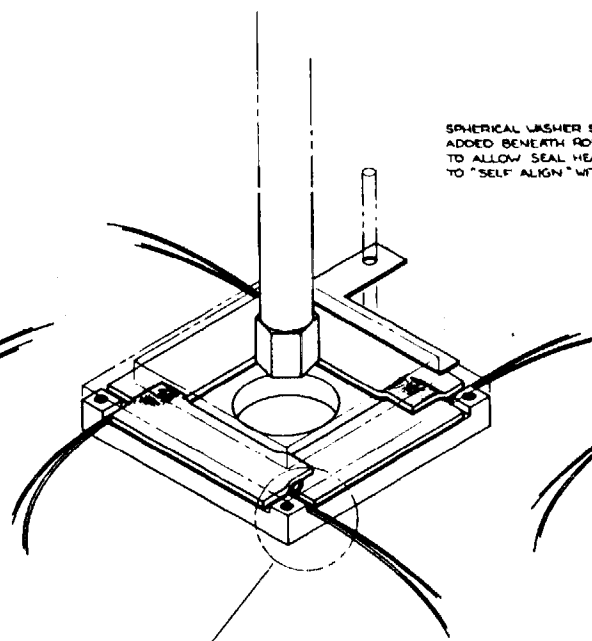
In deburring the seal platten, it is necessary to make a good 45-degree-chamfer on the inner lip of the seal bar to avoid partial necking or cutting of the lid film during the sealing operation. The condition of the outer lip of the seal is much less critical.

In order to obtain a satisfactory seal, parallel alignment of the seal platten with the lower anvil is also critical. With the sealer ram cylinder depressed and the sealing head cold, paper feeler gages were used to check seal platten clearances. The gap between platten and anvil at the rear of the package was found to be excessive. This was traced to poor attachment of the head assembly to the ram cylinder rod.

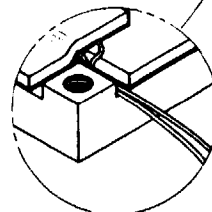
The problem was corrected by installation of a set of spherical washers in the joint between the ram cylinder rod and the sealing head assembly. It was also necessary to add a second seal head alignment rod to assure proper vertical alignment at the seal interface.



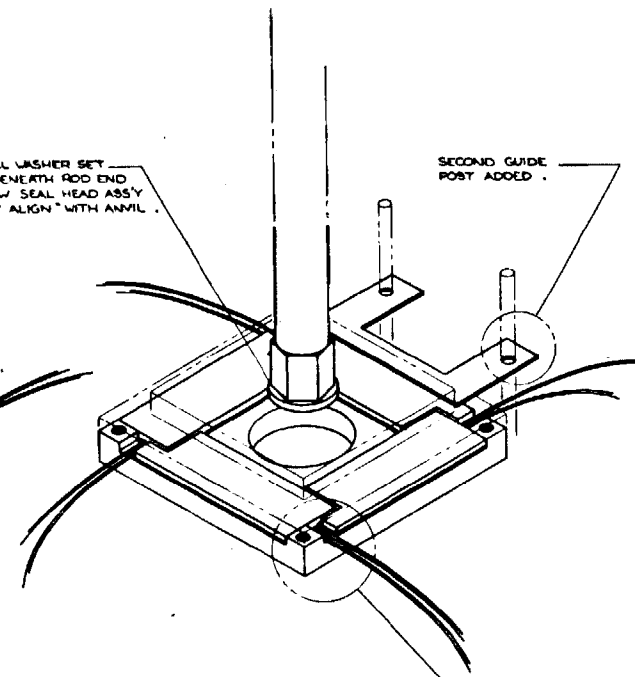
ORIGINAL CONCEPT



AS RECEIVED



SEALING PLATEN FACE WAS WARPED AND EDGES HAD NOT BEEN DEBURRED . HEATING PADS WERE OVERLAPPED AT INNER CORNERS TO CLEAR CORNER POSTS IN SEAL FACE (RUBBER CUSHIONS NOT CUT AWAY FOR CLEARANCE AT PINCH POINTS) . BOTH ENDS OF TWO PADS WERE DOWN AGAINST THE RAM . THE OTHER PAIR WERE OVERLAPPED AT BOTH ENDS . CREATING HOT SPOTS BETWEEN PADS AT THE ENDS OPPOSITE THE WIRES (SEE SHADED AREAS) . RIGID ATTACHMENT OF HEAD ASSEMBLY TO RAM CYLINDER ROD END DID NOT ALLOW SELF-ALIGNMENT OF SEAL FACES .



RECOMMENDATION

HEATING PADS OVERLAPPED AT ALTERNATE CORNERS WITH END OPPOSITE WIRE ON BOTTOM (RUBBER CUSHIONS CUT AWAY FOR CLEARANCE) FOR EVERY PAD . THIS ARRANGEMENT WILL PREVENT HOT SPOTS AND . . . HEATING PAD DAMAGE . . .

BOLDOUT FRAME 2

BOLDOUT FRAME 1

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Figure 2 **RECOMMENDATIONS TO IMPROVE SEAL HEAD ASSEMBLY, NASA FOOD PACKAGE**

7.0 LID THERMOFORM MOLD

During the developmental test phase of this program experimental samples of the lid configuration and sealed food packages were sent to the NASA Houston project office for evaluation. The final configuration (Figure 1) was approved by NASA, and FMC was directed to obtain cost information on a mold to be compatible with the AAA Plastic Equipment, Incorporated, Model MBF 2121A Thermoformer. Because there was no production of parts involved, difficulties were encountered in finding a supplier to bid on mold design and fabrication. One suitable bid was obtained for the work.

The lid development program for the revised lid design and sealing head modification had progressed successfully, and sufficient funds remained to permit fabrication of the production-type thermoformer mold. With NASA Houston's approval, a purchase order was placed. The thermoform mold supplier preferred to work with the lid drawing and the actual food cup itself to fabricate the desired thermoform mold shape. For this reason, the resulting thermoform mold and its vacuum box will be shipped to NASA Houston in place of an engineering drawing.

While FMC was developing the universal food package lid, the NASA Houston project office obtained a different type of seal head to test. The office requested that the thermoformer tooling FMC was fabricating be capable of forming lids without the center bubble dome for their experimental use. This was accomplished by having removable inserts in the mold. The bubble insert is removable to be replaced by a flat insert.

The thermoform mold that was fabricated is a four-cavity mold that forms four parts per draw. Mold proof-parts were made using the Springborn laminated film. Lids both with and without the bubble were fabricated for

delivery to NASA Houston, and for the seal strength tests conducted at Santa Clara. In no test did the seal fail; the material failed. The failure point was at the inside edge of the seal area. The lid film in the seal area was compressed to about 50 percent of adjacent film thickness.

The resulting average break strength in the shear direction was 17.1 pounds per inch, with a low of 12.5 pounds per inch and a high of 24.5 pounds per inch. The break strength in the peel direction averaged 11.4 pounds per inch with a low of 7 pounds per inch and a high of 19 pounds per inch.

These results show that the strength of the seal more than meets the 12-pound-per-inch requirement.

8.0 RECOMMENDATIONS

Observations made during this program and the previous EFS development program revealed that those food products that are of low bulk density and fragile cannot be packaged without damage when sealed under high vacuum.

Two events usually occur:

- The food is crushed, thus destroying its shape and physical structure
- The subsequent crushing and volume shrinkage of the food product generate stresses in the container cup, which cause gross distortion of the cup.

Fragile food products low in bulk density should thus be packaged at some experimentally determined lower vacuum pressure.

During the developmental work while thermoforming the lids, it was difficult to positively identify which side of the Springborn laminate the Saran coating was deposited upon. After forming and trimming there does not appear to be any convenient mechanical, visual, or tactile method of assuring the user that the Saran coating is indeed on the correct side of the finished part. One method found by FMC project personnel was to sandwich like lip sides of two lids together and fuse them to each other with an impulse sealer, then manually fail the fused joint by slowly peeling the two lids apart. Any observed delamination of the film in the fused area would indicate that the Saran film sides were fused together. If it does not delaminate, then the opposite side of the parts are coated.

It is recommended that some color, pattern, trace mark, or texture be added to the coated side of the film. This will visually aid the lid thermoform supplier, the receiving inspector, and the subsequent user to always assure that the film laminate is on the correct side of the lid.